

REMARKS

In the Office Action mailed May 8, 2003, claims 1-2 and 4-28 were examined. Claims 1-2 and 4-9 were rejected under 35 U.S.C. § 102(e) as anticipated by *Okutoh et al.* Claims 10-13, 21, 23-28 were rejected under 35 U.S.C. § 103(a) over *Okutoh* in view of *Chu et al.* Claim 14 was rejected under 35 U.S.C. § 103(a) over *Cuchiaro* in view of *Zhu et al.* Claims 15-20 were rejected under 35 U.S.C. § 103(a) over *Cuchiaro* in view of *Izuha et al.* Claim 22 was rejected under 35 U.S.C. § 103(a) over *Okutoh* in view of *Chu* and further in view of *Cuchiaro*. These rejections are respectfully traversed in view of the above amendments and the remarks that follow.

A. Cancellation of claims 1, 2, 4-11 and 13.

Claims 1, 2, 4-11 and 13 are cancelled herein, without prejudice to the subject matter thereof. As a result of this cancellation, claims 12 and 14-28 remain pending, the § 102(e) anticipation rejection of claims 1-2 and 4-9 by *Okutoh* is mooted and the § 103 rejection of claims 10-13, 21 and 23-28 over *Okutoh* in view of *Chu* is limited to claims 12, 21 and 23-28.

B. Some Distinguishing Features of the Present Invention.

With regard to semiconductor devices having a ferroelectric capacitor, the present invention as claimed eliminates the problem of peeling off of the ferroelectric capacitor insulation film forming the ferroelectric capacitor, by conducting the crystallization process in an atmosphere of an oxidizing gas under a reduced total pressure of from 1 Torr to 40 Torr as set forth in amended claim 12, or by conducting the crystallization process in an atmosphere containing an oxidizing gas with a fraction of at least 1% to less than 20% in volume, such that the step of crystallizing the ferroelectric film is conducted by supplying O₂ controlled to cause an oxidation in the Ti atoms reached a surface of said lower electrode from the layer part containing Ti atoms as set forth in claim 14.

Further, as set forth in claim 21, an oxidizing step is conducted upon the ferroelectric film, after the crystallizing step thereof conducted in an atmosphere containing a non-oxidizing gas and an oxidizing gas, such that

the density of pinholes formed in the ferroelectric film during the crystallizing step, is reduced.

Further, the present invention provides a semiconductor device having a characteristic structure as recited in claim 15 as a result of such a process.

C. Claims 12, 21 and 23-28 are Patentably Distinguishable over Okutoh in view of Chu.

Okutoh describes the process of forming a semiconductor device having a ferroelectric capacitor in which the resistance of the PZT film forming the ferroelectric capacitor against hydrogen is improved. In order to achieve this object, *Okutoh* uses an alloy of platinum and rhodium for the upper electrode of the ferroelectric capacitor. *Okutoh* also describes the use of a mixed atmosphere of nitrogen and oxygen having the ratio of 4:1 for the crystallization process of the PZT film. *Okutoh* is, however, silent about the reason why such a mixed gas atmosphere is used or about the function and/or effect of using such a mixed gas atmosphere.

With regard to independent claim 12, *Okutoh* is silent about the use of a reduced pressure of from 1 to 40 Torr during the ferroelectric film crystallization step. Thus, even when *Okutoh* is combined with *Chu*, the specific pressure range as recited in claim 12 is neither taught nor suggested. Further, neither *Okutoh* nor *Chu* provides a motivation to combine *Okutoh* with the teachings of *Chu* relating to use of a reduced oxygen pressure during the crystallization process of the ferroelectric film. Thus, amended claim 12 is patentably distinguishable over the combined teachings of *Okutoh* and *Chu*.

With regard to independent claim 21 and as noted in the specification at page 19, lines 6-7, by performing a second RTA process, the number, and hence the density, of the pinholes in the PLZT film is reduced as compared with the case in which no second RTA process is conducted. Neither *Okutoh* nor *Chu* teaches or suggests the existence of the pinholes in the ferroelectric film or decrease of the pinhole density as a result of such an oxidizing step conducted after the crystallizing step. Thus, amended claim 14 is also patentably distinguishable over the combined teachings of *Okutoh* and *Chu*.

Claims 23-28 each depend directly or indirectly from amended claim 21, and thus also incorporate the patentably distinguishable features of claim 21 identified above. Accordingly, withdrawal of the § 103 rejection of claims 12, 21 and 23-28 over the combination of *Okutoh* and *Chu* is proper and respectfully requested.

D. Claim 14 is Patentably Distinguishable over Cuchiaro in view of Zhu.

With regard to independent claim 14, it is noted that *Cuchiaro* is silent about the migration of Ti atoms to the surface of the lower electrode or oxidation of the Ti atoms thus migrated. While *Zhu* describes such migration of the Ti atoms through the lower electrode, the *Zhu* process anneals the lower electrode separately from the crystallization process of the ferroelectric film and conducts the annealing of the lower electrode in a pure Ar atmosphere free from oxygen. Thus, the Ti compound formed on the surface of the lower electrode in *Zhu* is a TiO_x compound with a relatively small oxygen content (x) that gives the TiO_x compound a composition close to metallic Ti. Such a compound is unstable and easily undergoes oxidation, so that the ferroelectric films obtained by *Zhu* would easily result in the peeling problem that is addressed by the claimed invention.

Contrary to *Zhu*, the present invention successfully avoids this problem of ferroelectric film peeling caused by the oxidation of the TiO_x compound at the surface of the lower electrode, by (1) conducting the crystallization of the ferroelectric film and the annealing of the lower electrode simultaneously after the ferroelectric film is deposited on the lower electrode in the atmosphere containing an inert gas and an oxidizing gas, and (2) by the feature of controlling the supply of O₂ so as to cause an oxidation in the Ti atoms reached a surface of the lower electrode from the layer part containing Ti atoms. Further, the TiO_x compound formed in the present invention with large value for the compositional parameter x, can function the effective nuclei for the growth of the ferroelectric film such as a PZT film.

Thus, claim 14 as amended herein, is patentably distinguishable over the combination of *Cuchiaro* and *Zhu*.

E. Claims 15-20 are Patentably Distinguishable over Cuchiaro in view of Izuha.

Amended claim 15 includes the following limitation:

said ferroelectric film essentially consisting of columnar crystal grains extending continuously from a bottom surface of said ferroelectric film to a top surface of said ferroelectric film and having a substantially uniform grain diameter of less than about 200 nm.

Support for the added limitation is found in FIGS. 7A and 7B in the present invention.

Izuha describes a columnar microstructure for the ferroelectric film in which the size of the columnar grains A is preferably in the range from 5 to 500nm. FIG. 4A of *Izuha* is a “schematic” diagram (col. 3, lines 65-67) and is believed to not literally represent grain diameter distributions in a ferroelectric film. Instead, and as is clear from the specification of *Izuha* that FIG. 4A is intended to show the existence of columnar crystal structure in the lower electrode 4, the STO ferroelectric film 5 and the upper electrode 6. It is reasonable to conclude that the columnar crystals in FIG. 4A are a schematic representations only—not illustrating literal relationships—because all the columnar crystals in FIG. 4A have the substantially same diameter, and it is believed factually impossible to have a real ferroelectric capacitor with the structure of FIG. 4A in which the grain diameter is the same among all the crystals constituting the ferroelectric film.

It is thus improper to extrapolate from the *Izuha* specification—which characterizes FIG. 4A as a schematic—to conclude that *Izuha* teaches the claimed limitation relating to a substantially uniform grain diameter of less than about 200 nm in a ferroelectric film. Because *Cuchiaro* also fails to teach this recited feature, independent claim 15 and dependent claims 17-20 are patentably distinguishable over the combination of *Izuha* and *Cuchiaro*.

F. Claim 22 is Patentably Distinguishable over the Combination of Okutoh, Chu and Cuchiaro.

As mentioned above relative to independent claim 21, by performing a second RTA process, the number, and hence the density, of the pinholes in

the PLZT film is reduced as compared with the case in which no second RTA process is conducted. None of *Okutoh*, *Chu* or *Cuchiaro* teaches or suggests the existence of the pinholes in the ferroelectric film or decrease of the pinhole density as a result of such an oxidizing step conducted after the crystallizing step. Thus, amended claim 22 is also patentably distinguishable over the combined teachings of the cited references.

G. Conclusion.

Pending claims 12 and 14-28 being patentably distinguished over the references of record, withdrawal of the § 102 and § 103 rejections is proper and respectfully requested. Should any issues remain, the Examiner is kindly asked to telephone the undersigned.

Although no fee is believed due for this filing, any required fee may be charged to Deposit Account No. 50-1123.

Respectfully submitted,



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